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ABSTRACT

To test the hypotheses that gifted Ss will be better able to supply missing conclusions to conditional syllogisms as a factor of maturation and that the hierarchy of difficulty in supplying conclusions will be from affirming the antecedent and denying the consequent, to linear transitivity to nonlinear transitivity, and finally to conditional chains: 160 gifted children (ages 4 to 12) were studied. Findings validated both hypotheses. There was a developmental pattern in the ability to supply the missing conclusions, with an increase noted at each age level until age 9 when ability leveled off until age 11. The hierarchy existed, but was clustered into two groups (one the first two principles, the other the last three) with conditional chains by far the hardest principle for the Ss to grasp. (PHR)

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Introduction and Statement of the Problem

Logical ability in children has received much attention, probably in large measure due to the influence of Piaget (10) who has claimed that children cannot handle formal propositional logic until the age of eleven or twelve. Investigators influenced by Piaget's theory have concentrated mainly on classification and conservation, however, rather than formal logic. In a recent critical analysis of Piaget's theory, Ennis (2) effectively pointed out that Piaget's conception of logic is inadequate. After a lengthy analysis, Ennis stated that Piaget may not even be talking about deductive logic (2, p. 39). Recently, there is a small but growing body of literature clearly exploring various aspects of deductive logic, including investigations by Donaldson (1), Howell (6), Ennis and Paulus (4), Gardiner (5), Miller (8) and O'Brien and Shapiro (9). The primary areas explored in those studies were conditional and class logic including the ability to deduce and assess conclusions. Though there have been a few investigations examining the acquisition of conditional logic under age eleven, only Ennis (3) has attempted

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to determine which of the basic principles of conditional logic are known by primary school children. His study utilized children in the first, second, and third grades and measured their knowledge of logical principles via a test requiring children to respond to propositional statements about concrete objects in view of the subjects. His results indicated that many primary school students have already mastered some of the basic principles of conditional logic. Although dealing with class logic, a recent study of four to eleven-year-old children by Wolf and Shigaki (12) indicated that even a few four-year-old children can perform logical reasoning when they are required to supply conclusions to class syllogisms. The present study then was conducted to extend the research on conditional logic down to age four and to provide a wider base for the developmental trends by testing an eight-year-age span. In addition, the instrumentation was different from the Ennis study in that concrete objects were not used since the earlier Wolf and Shigaki study showed they were not necessary when testing class logic. Further, the instrument developed for this study required subjects to generate their own responses, rather than to choose from among given alternatives.

The first hypothesis was developed to test whether significant differences in children's ability in conditional logic do exist below the age of eleven years when a verbal logic test is used. If children do not attain logic prior to ages eleven or twelve as Piaget has contended, then there would be no differences below that age as no children would have the ability. However, based on the few preliminary studies that have been done, it is assumed by the investigators that a difference will be found and that children will score higher as they increase in age. Since Ennis' study revealed children of six years of age (WISC IQ, $\bar{X}=108$, $SD=14$) who could do some conditional reasoning, gifted children from four years

of age (Stanford-Binet or WISC IQ, $\bar{X}=143$, $SD=11$) were used for this study as it was assumed that their logical reasoning would be accelerated over that of the average child. A top age level of eleven was chosen to test Piaget's contention that children cannot handle formal propositional logic until that age. Therefore, the sample includes children from ages four through eleven.

The second hypothesis was developed to test whether certain principles of conditional logic are more difficult than other principles for children of ages four through eleven. The difficulty of some principles for subjects in grades four through twelve has been studied by a few investigators. Roberge's (11) summary of these studies clearly indicates that the principle of affirming the antecedent is the easiest. Two out of three studies for elementary grade children cited by Roberge indicated that denying the consequent is the next easiest for children from those grades. In the study of first, second and third grade children, Ennis (3) found that some children had mastered the principle of denying the consequent. Further, he found that this principle was easier for the children than the conditional chains. No studies have been found on transitivity, as defined in this paper, as compared to the conditional principles. However, a transitivity syllogism appears more difficult because it has three terms whereas both affirming the antecedent and denying the consequent have only two terms. In addition, it has been commonly accepted that linear transitivity is easier than non-linear transitivity since the three terms increase or decrease in the same direction for linear transitivity and in opposite directions for non-linear transitivity. Finally, conditional chains seem conceptually more difficult than transitivity since the latter deals with relative position regarding a single attribute (e.g., height, see Table I) whereas in a chain a sequence is developed among three attributes (e.g., exercising, strength and health). Items based on valid syllogisms were

included in the study since it has been found that they are easier than fallacies. It was hypothesized, therefore, that a hierarchy of difficulty would be found for the principles of logic included in this study. Affirming the antecedent would be the easiest principle, with denying the consequent next, followed by linear transitivity, non-linear transitivity, and conditional chains.

In summary, the hypotheses are as follows:

Hypothesis 1: There will be a significant difference in the scores and proportion of gifted subjects (Stanford-Binet or WISC IQ 130+) from age level to age level in the ability to supply missing conclusions to conditional syllogisms. The younger the child, the lower will be his score.

Hypothesis 2: There will be a hierarchy of difficulty for gifted children (Stanford-Binet or WISC IQ 130+) in supplying conclusions to various types of conditional syllogisms. Affirming the antecedent will be the easiest, denying the consequent next, followed by linear transitivity, non-linear transitivity, and conditional chains.

Procedure

The sample was comprised of 160 children, twenty from each of the age levels four through eleven, selected randomly from a school for the gifted in New York City with a mixed ethnic population. All of the children in the sample had been tested with the Stanford-Binet Intelligence Test or the Wechsler Intelligence Scale for Children and had obtained a score of 130 or higher. The mean IQ score for the sample was 143, with a SD of 11.

The instrument for measuring children's ability to supply missing elements to conditional syllogisms was a fifteen item subtest of the Shigaki-Wolf Logic Test. The subtest was comprised of an equal number of items to assess the principles of affirming the antecedent, denying the consequent, linear

transitivity, non-linear transitivity and conditional chains. A test-retest reliability of .90 was established on the full scale with a reliability of .87 for the conditional subtest. Validity was determined by having a logician who regularly teaches logic classes at New York University analyze each item to determine (1) the correct answer to the item, (2) the element of logic that the test item is assessing, and (3) whether each item is a valid form of that aspect of logic. Examples of the principles tested together with their symbolic forms are presented in Table I.

Data were collected through an individual oral session with each child. The child's responses were recorded in spaces provided on the test form and each session was tape recorded. Counterbalancing was done across all age levels to eliminate the effects of tester, room, and time of day. Each subject's test responses were scored by two judges. Those few responses on which the judges disagreed were checked through the audio recordings. Agreement was reached on all responses after this check.

Results and Discussion

An 8 X 5 factorial analysis of covariance was computed with repeated measures on the last factor (8 levels of age; 5 principles of logic). To eliminate group differences due to intelligence, IQ scores were used as the covariate. A .01 level of significance was utilized for all analyses. The results of the analysis are presented in Table II. As can be seen from this table, significant F values were obtained for the main effects of age ($F=18.778$, $df=7,151$) and logic principles ($F=404.144$, $df=4,607$). An interaction effect between age and logic principles ($F=2.367$, $df=28,607$) was also found. There is also a significant difference ($F=7.667$, $df=1,151$) between the age groups on the covariate or IQ, showing that the selection

TABLE I
CONDITIONAL LOGIC PRINCIPLES WITH REPRESENTATIVE TEST ITEMS

Principle	Symbolic Form	Test Item
1. Affirming the Antecedant	If p, then q p Therefore, q	If the dress is bright, Jan will wear it Sunday. The dress is bright. So? (Jan will wear it Sunday).
2. Denying the Consequent	If p, then q Not q Therefore, not p	If the book is red, it belongs to Carl. It does not belong to Carl. So? (It is not red).
3. Linear Transitivity	$A > B$ $B > C$ So $A > C$	David is funnier than Mark. Mark is funnier than Jeff. What else is true? (David is funnier than Jeff).
4. Non-linear Transitivity	$A < B$ $A > C$ So $B > C$	Tom is shorter than Allan. Tom is taller than Peter. What else is true? (Allan is taller than Peter).
5. Conditional Chain	If p, then q If q, then r p, therefore, r	If Jim exercises, then he will be strong. If he is strong, then he will be healthy. What else is true? (If Jim exercises, then he will be healthy).

TABLE II
ANALYSIS OF COVARIANCE FOR AGE AND PRINCIPLE

Source	SS	df	MS	F
Between subjects				
Age	15.581	7	2.226	18.778***
Covariates	0.909	1	0.909	7.667**
Subjects within groups	<u>17.899</u>	<u>151</u>	0.119	
Total	34.389	159		
Within Subjects				
Principle	88.294	4	22.073	404.144***
Age x Principle	3.620	28	0.129	2.367***
Covariates	0.000	1	0.000	
Principle x Subjects within groups	<u>33.153</u>	<u>607</u>	0.055	
Total	125.067	640		

** Significant at the .007 level.

***Significant beyond .001 level.

of analysis of covariance as the statistic was necessary. The proportion of correct logic responses by age when adjusted and unadjusted for IQ are presented in Table III.

Further analyses of the main effects were conducted using the Scheffé test (Kirk, p. 269). The conservative Scheffé test was purposefully utilized as some of the assumptions of the analysis of covariance had not been met. The results of that analysis are presented in Table IV. Significant differences were found at three-year increments and up for ages four, five and six, i.e., the differences between ages four and seven, four and eight and the remaining age groups are significant. The only exception is the non-significant difference between ages six and ten.

The results of the Scheffé test for the main effect of logic principles are tabulated in Table V. As can be noted from this table, while there is no significant difference between the principles affirming the antecedent and denying the consequent, there are significant differences between these two principles and the remaining three principles, i.e., linear transitivity, non-linear transitivity and chains. Significant differences were also found between the two types of transitivity and conditional chains.

As hypothesized, there is a developmental pattern in the ability of young children to supply missing conclusions to conditional syllogisms. This pattern is plotted in Figure 1. As can be seen from that figure there is an increment with each age from age four through age nine with a plateau effect between ages nine and eleven. This plateau effect at the 60% correct response level for total score may be explained by referring to Figure 2. It can be seen that for ages nine through eleven children have reached the ceiling for the principles affirming the antecedent and denying

TABLE III

MEANS ON IQ AND LOGIC BY AGE

Age	$\bar{X}$ IQ	$\bar{X}$. Proportion Correct on Logic Test	
		Adjusted	Unadjusted
4	152	.190	.220
5	149	.264	.283
6	139	.379	.363
7	143	.470	.470
8	140	.510	.500
9	144	.600	.603
10	139	.588	.573
11	139	.596	.583

TABLE IV
SCHEFFÉ TEST FOR DIFFERENCES BETWEEN MEANS BY AGE
(Proportion of Correct Responses)

	Age						
	5	6	7	8	9	10	11
4	.074	.189	.280*	.320*	.410*	.398*	.406*
5	-	.115	.206	.246*	.336*	.324*	.332*
6		-	.091	.131	.221*	.209	.217*
7			-	.040	.130	.118	.126
8				-	.090	.078	.086
9					-	-.012	-.004
10						-	.008
11							-

* Significant beyond the .01 level.

TABLE V

SCHEFFÉ TEST FOR DIFFERENCES BETWEEN MEANS BY LOGICAL PRINCIPLE
(Proportion of Correct Responses)

	Principle			
	DC	L-T	NL-T	Ch
Affirming the Antecedent	.052	.623*	.679*	.783*
Denying the Consequent	-	.571*	.627*	.731*
Linear Transitivity		-	.056	.160*
Non-linear Transitivity			-	.104*
Conditional Chain				-

* Significant beyond the .01 level.

FIGURE 1

PROPORTION CORRECT ON CONDITIONAL LOGIC TEST BY AGE

(Adjusted for IQ)

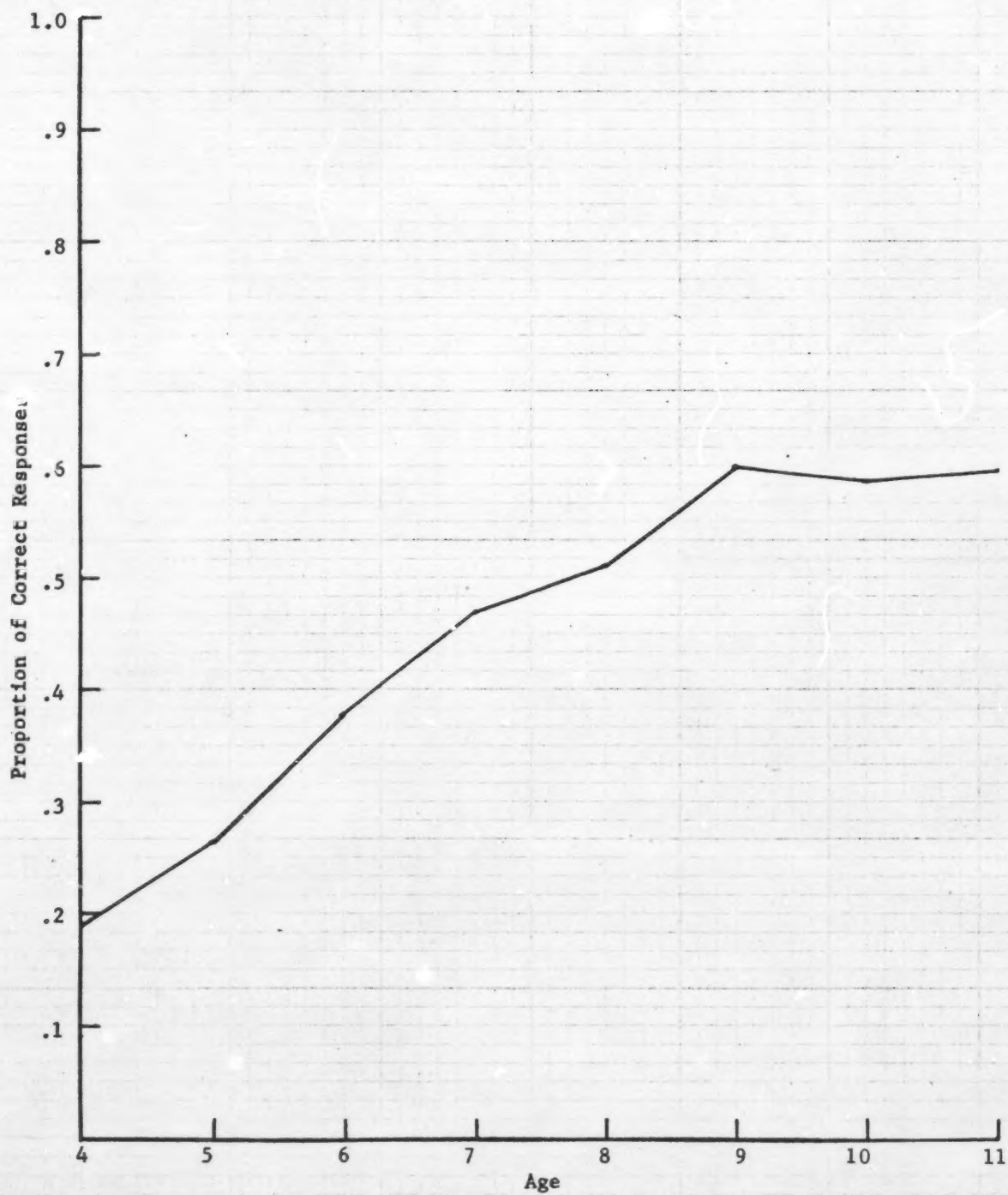
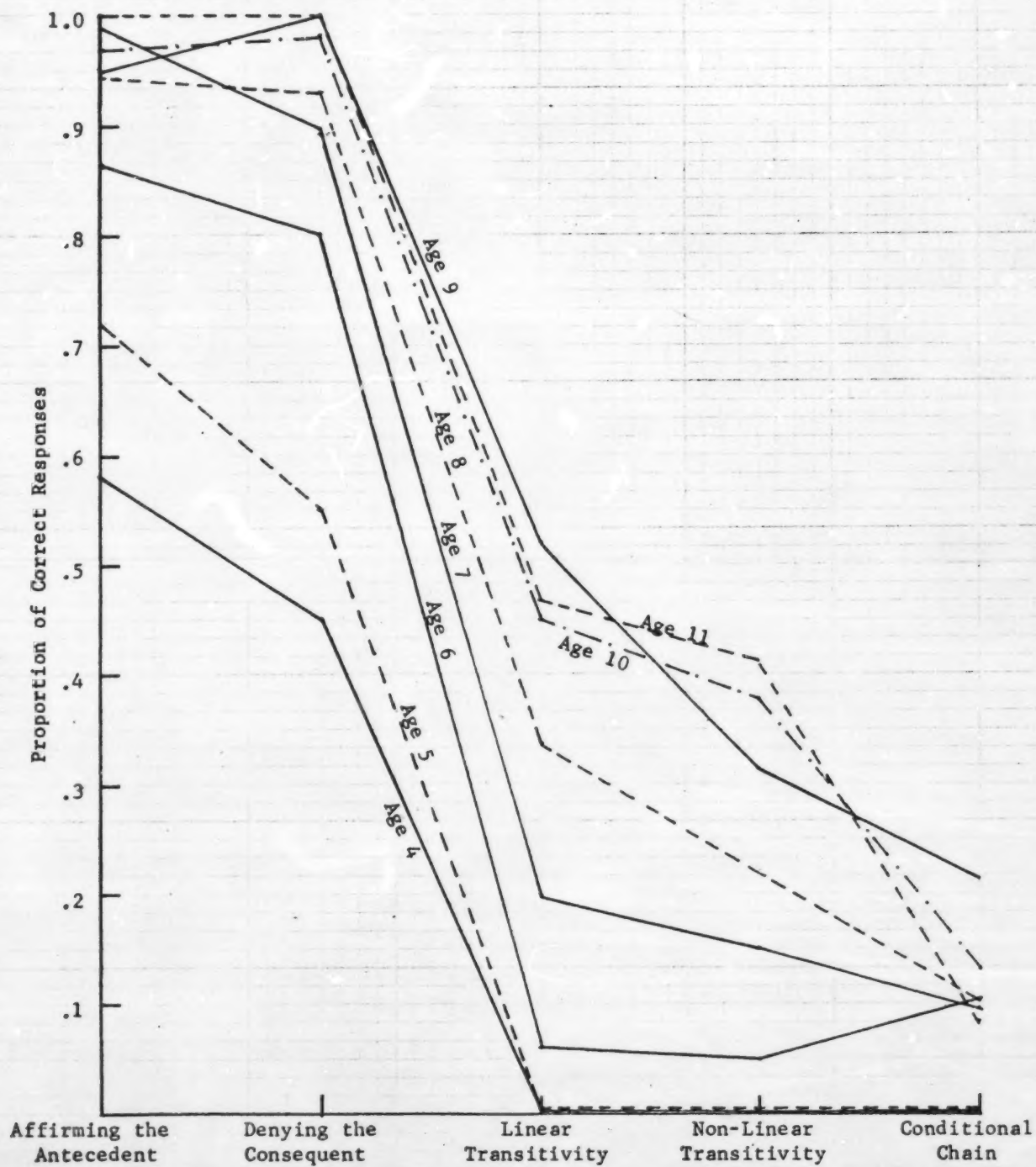


FIGURE 2

PROPORTION CORRECT ON CONDITIONAL LOGIC TEST BY AGE AND PRINCIPLE

(Adjusted for IQ)



the consequent, while leveling off near the 44% correct response level on the two transitivity chains. In referring back to Table IV, it has been reported that from age seven through age eleven no significant differences were found among age groups. The differences found at ages four, five, and six at three year intervals and above were due to a cumulative effect within the three-year span. The three-year difference between ages seven and ten failed to be significant since increments were made only between ages seven and nine with no gains between ages nine and ten due to the plateau effect.

The analysis revealed that the hierarchy of difficulty for the principles of logic was the same as that hypothesized. However, as can be seen from figure 2, rather than a linear ordering, the principles cluster in two groups. Affirming the antecedent and denying the consequent are significantly easier than linear transitivity, non-linear transitivity and conditional chains. A ceiling effect occurs on affirming the antecedent and denying the consequent from age seven, contributing to the lack of significant differences between them. However, affirming the antecedent appears to be easier than denying the consequent at the younger ages. With a normal population the differences between affirming the antecedent and denying the consequent might become more pronounced throughout the age levels four through eleven. The Scheffé test did not yield a significant difference between linear and non-linear transitivity. In examining Figure 2, it can be seen that few differences on these two principles occur at ages four, five and six primarily since few of the items of either type were answered correctly. There also seems to be a plateau effect at the upper end of the age span at ages ten and eleven where approximately 40% of the items for both principles were answered correctly. Only at ages eight and nine did

linear transitivity seem to be easier than non-linear transitivity. As hypothesized, the conditional chain was the most difficult principle. In Figure 2 it can be noted that not only were the scores lower for that principle, but the range was more constricted, 0 to 22% correct, than for any other principle.

While the present study offers support for the contention that children under the age of eleven have mastered some principles of logic, there is a need to systematically extend research in this area. The present investigators are currently analyzing data concerning the acquisition of principles of class and conditional logic with both gifted and normal samples. In addition to the heuristic nature of this work, the study has practical importance as well. The teacher or administrator who is making curriculum decisions about certain types of instruction can be assisted by knowledge that certain children have already mastered certain principles of logic. It is suggested that these practical applications should wait, however, until more extensive studies can be conducted.

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